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ADVANCED ADAPTIVE ANTENNA TECHNIQUES

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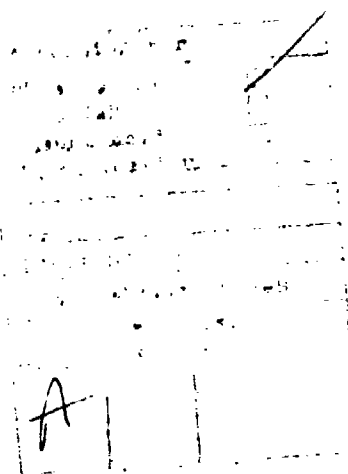A

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This report describes progress under Naval Air Systems Command Contract N00019-80-C-0181 during the second quarterly period. Research on advanced adaptive antenna techniques is summarized.

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CONTENTS

I. INTRODUCTION

This report describes progress under Naval Air Systems Command Contract N00019-80-C-0181 during the second quarterly period. This contract involves adaptive array studies in two areas: (1) the effects of element patterns and signal polarization on adaptive array performance, and (2) the capability of pulsed and swept CW jamming against adaptive arrays. In addition, a monograph on adaptive arrays is being prepared under this contract.

During the second quarterly period, we have concentrated on two of the above areas: the effects of signal polarization, and the monograph. Progress in these two areas is described below.

II. PROGRESS

1. The Effects of Signal Polarization
on Array Performance

During the previous quarter we computed the performance of an array of three tripoles against an aribtrarily but completely polarized* interference signal [1]. It was found that this array is extremely effective against such interference. The interference can significantly reduce the array output signal-to-interference-plus-noise ratio (SINR) only if it arrives from the same direction and has the same polarization as the desired signal. Therefore, to be effective against such an array, a jammer will be forced to use cross-polarized jamming, i.e., to transmit two

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*A completely polarized electromagnetic wave is one with a single, fixed polarization. This polarization differs from a partially polarized, or a randomly polarized wave, for which the state of polarization changes randomly with time [2].

independent jamming signals on cross-polarized elements. (This results
in a randomly polarized wave, in contrast to the completely polarized
wave described above.) During this quarter, we have therefore extended
last quarter's work by computing the performance of a single tripole and
a 3-tripole array against such cross-polarized jamming.

First, we calculated the output SINR from a single tripole array
with a desired signal and a cross-polarized interference signal incident
on the array. The SINR was computed as a function of the incidence angles
of the desired signal and interference, and of the desired signal polari-
zation. In this analysis, each polarization component of the interference
is assumed to have a flat bandlimited power spectrum.

The results of this study show, as expected, that the performance
of the single tripole against cross-polarized interference is poorer
than it is against a completely polarized interference signal. The rea-
son is that a cross-polarized interference signal uses up two degrees of
freedom, whereas a completely polarized interference signal uses up only
one. Hence, the tripole has less flexibility left for optimizing de-
sired signal polarization. If the desired signal has linear polarization,
the output SINR from a single tripole array with cross-polarized inter-
ference is poor for many arrival angles. But if the desired signal is
circularly polarized, the SINR is only slightly lower than it is with
completely polarized interference.

Figures 1-3 illustrate these comments. Figure 1 shows the tripole
antenna, with the angles θ and ϕ defined. Figure 2 shows the SINR per-
formance of the tripole with completely polarized interference, and Fig-
ure 3 shows the SINR with cross-polarized interference. In both cases,
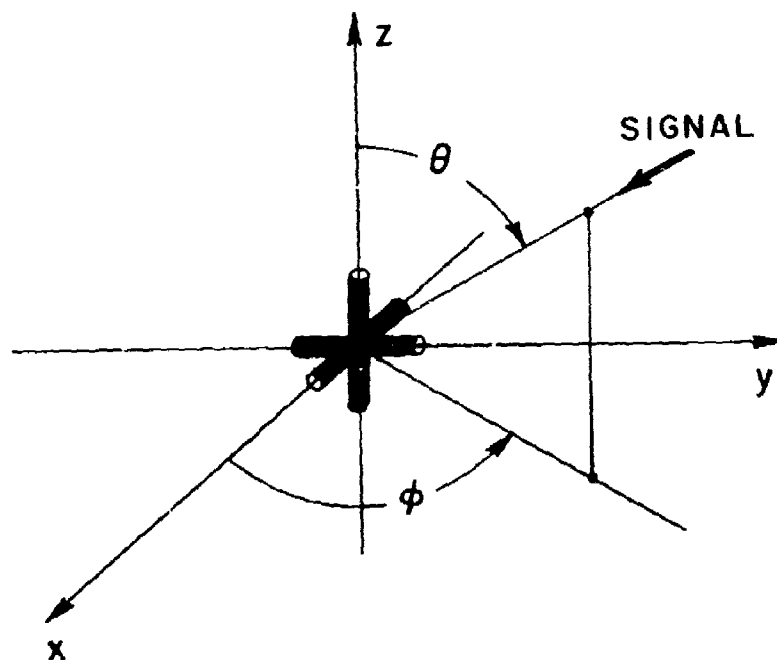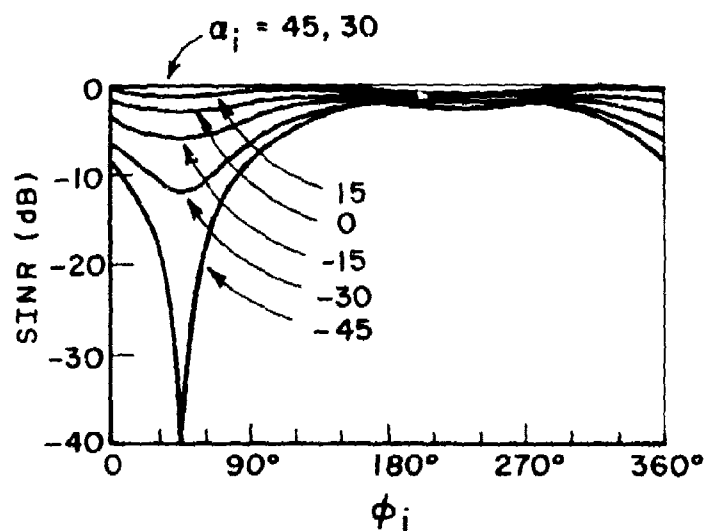the desired signal has circular polarization.

2

Figure 1. The tripole antenna.

Figure 2. SINR of tripole with completely polarized interference.
(θ_d=45, ϕ_d=45, α_d=45, β_d=0, θ_i=45, β_i=0
SNR=0 dB, INR=40 dB)

3
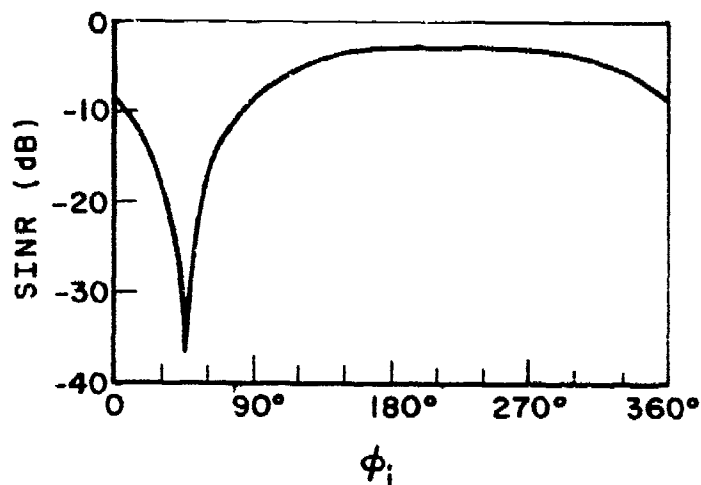
Figure 3. SINR of tripole with cross-polarized interference.
(θ_d=45, ϕ_d=45, α_d=45, β_d=0, θ_i=45
SNR= 0 dB; Total INR=40 dB)

In Figure 2, the desired signal arrives from θ_d = 45° and ϕ_d = 45°
with polarization ellipticity angle α_d = 45° and orientation angle β_d=0°.
(These values of α_d and β_d correspond to left circular polarization.)
The desired signal has 0 dB signal-to-noise ratio (SNR). The interference
arrives from θ_i = 45° with orientation angle β_i = 0° and an interference-
to-noise ratio (INR) of 40 dB. Figure 2 shows the output SINR from the
array as a function of the interference angle ϕ_i. Seven curves are shown
for different values of interference ellipticity: α_i = -45°, -30°, -15°,
0°, 15°, 30° and 45°. The curve with the lowest SINR is for α_i = 45°,
when the interference has the same polarization as the desired signal.
For this case the SINR drops to -40 dB when the interference arrives from
the same direction as the desired signal. But for other values of α_i,
the SINR is better, even when the interference arrives from the same di-
rection as the desired signal.

4

Now consider Figure 3, which shows the output SINR from the same array when the interference is cross-polarized, i.e., when it consists of two independent signals transmitted from the same direction on orthogonal linear polarizations (one polarized in the $\hat{\theta}$-direction and the other in the $\hat{\phi}$-direction). The desired signal parameters are the same in Figure 3 as in Figure 2. Each component of the interference has an INR of 37 dB, so the total interference power on both polarizations is 40 dB above noise, the same as in Figure 2. Figure 3 again shows the output SINR from the array as a function of ϕ_i.

Comparing Figures 2 and 3 shows that the SINR of the tripole is slightly lower with the cross-polarized jammer than with the completely polarized jammer. However, the difference is small.

An important point to note is that a cross-polarized jammer always forces the SINR to be low when the interference arrives from the same direction as the desired signal. A completely polarized jammer does not necessarily force the SINR to be low when the two signals come from the same direction. Only if the interference polarization is the same as that of the desired signal does it do so. The cross-polarized jammer forces the array to produce a null for both polarizations in the interference direction. Hence the array cannot receive any desired signal from this direction.

During this quarter, we have also computed the performance of an array of three tripoles (i.e., nine elements) against a cross-polarized jammer. These studies are similar to those described above for the single tripole, but also include the effects of interference bandwidth. (Bandwidth has no effect on the performance of a single tripole.) Figures 4 and 5 show typical results. For both figures, the desired signal arrives from $\theta_d = 45^\circ$ and $\phi_d = 45^\circ$ with $\alpha_d = 45^\circ$ and $\beta_d = 0^\circ$, i.e., with left circular polarization. The SNR is 0 dB. In both figures, the interference arrives from $\theta_i = 45^\circ$ with an INR of 37 dB on each polarization component,

5

or a total INR of 40 dB. The figures again show the array output SINR versus ϕ_i. Figures 4 and 5 differ only in the choice of interference bandwidth. Figure 4 is for zero bandwidth, and Figure 5 is for 10% bandwidth. It is seen that there is relatively little change between the two curves. This is an important point, which we discuss below.

We have learned that an extremely helpful advantage of using co-located cross-polarized elements in an adaptive array is that it greatly reduces the problem of interference bandwidth. Normally, when only one polarization is received by an adaptive array, the SINR from the array drops quickly as interference bandwidth is increased. Even a small bandwidth can produce a substantial drop in SINR. This degradation occurs because nonzero bandwidth causes the interference signals in the different array elements to be partially decorrelated. Hence, with nonzero bandwidth, the interference cannot be nulled as well by subtracting one element signal from another. However, when two or more elements are located at the same position, as in the tripole antenna, there is no interelement time delay for the interference, regardless of its arrival angle. As a result, no decorrelation occurs, and the performance of the tripole is unaffected by interference bandwidth.

In addition, when two or more tripoles are used in a larger array, the SINR performance of the entire array is always at least as good as that of one of the tripoles by itself. (I.e., the array feedback can always turn off the weights in all the elements of the array except for one tripole.) Thus, with wideband interference, the SINR from an array of tripoles cannot be worse than the SINR from a single tripole, and the SINR from a single tripole is not affected by bandwidth. Moreover, if the desired signal has circular polarization, the single tripole SINR is quite respectable, as may be seen in Figure 3. Thus, the use of co-located, cross-polarized elements in an array turns out to have the important side benefit of reducing the problem of interference bandwidth.
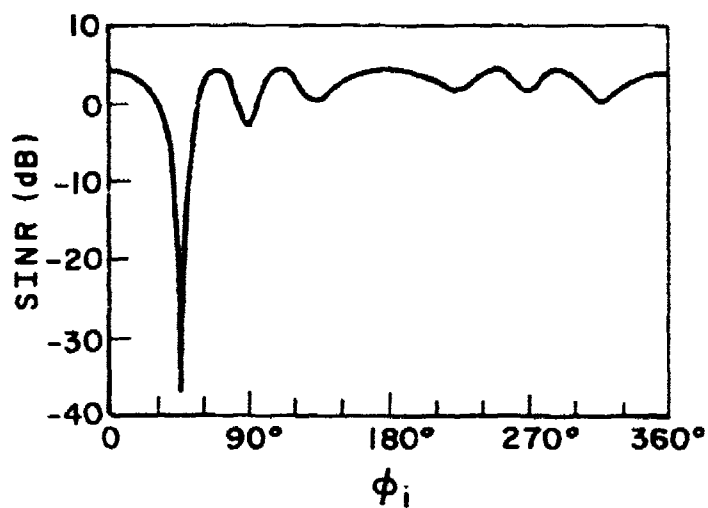
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Figure 4. SINR of 3-tripole array with cross-polarized interference (zero bandwidth). (θ_d=45, ϕ_d=45, α_d=45, β_d=0, L/λ=2 SNR=0, Total INR=40 dB)
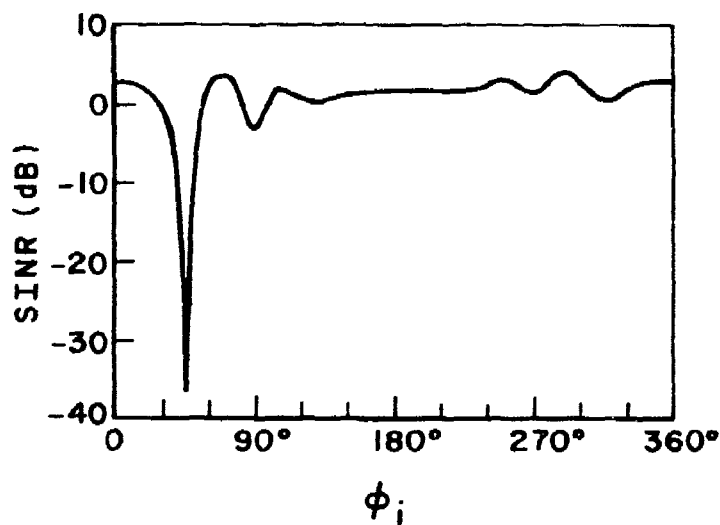

Figure 5. SINR of 3-tripole array with cross-polarized interference (10% bandwidth). (θ_d=45, ϕ_d=45, α_d=45, β_d=0, L/λ=2 SNR=0 dB, Total INR=40 dB.)

7

Comparing Figures 4 and 5 shows that the performance degradation
with 10% bandwidth is quite small. It may be shown that the performance
of an adaptive array receiving only one polarization is much poorer with
10% bandwidth. (See, for example, Reference 3).

2. Monograph

During the second quarter, we have also put considerable effort into
the adaptive array monograph. At this date, Chapter III of the monograph
is essentially finished. (The first three chapters constitute most of
the monograph. Two additional very short chapters are planned on appli-
cations.) Presently, 438 types pages of manuscript have been completed.

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